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EVALUATION OF ELECTROFORMED NICKEL TO  
301 STAINLESS STEEL RESISTANCE SPOTWELDS  
at 78°F and -423°F.

GD/C MRG - 288

January 25, 1962

Prepared by: L.D. Girton

25 January 1962

SUBJECT: "Evaluation of Electroformed Nickel to 301 Stainless Steel Resistance Spotwelds at 78°F and -423°F" <sup>19455</sup>

ABSTRACT: As evaluated by the notched tensile test .062" electroformed nickel had excellent toughness at -423°F having a notched-unnotched ratio of 1.21. The electroformed nickel resistance spotwelded to .020" type 301 (0-71004) stainless steel met the shear and tension requirements of MIL-W-6858A. The .020"-301 to .062" electroformed nickel spotweld tension strengths increased in value at -423°F as compared to spotweld tension strengths in .020" type 301 welded to Inconel-X and to itself which decreased at cryogenic temperatures. *auth*

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25 January 1962

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FROM: Materials Research Group, Dept. 592-1

SUBJECT: Evaluation of Electroformed Nickel to 301 Stainless Steel  
Resistance Spotwelds at 78°F and -423°F

#### INTRODUCTION:

Electroforming, sometimes called, "cold casting" or electro-fabricating is a method of fabricating parts by depositing a metal on a mandrel of the desired shape. The mandrel can either be extracted and reused, or dissolved away, depending upon the shape of the part. Deposition or metal build-up rate is usually in the range of .001" - .003" per hour. Although many metals can be deposited by this process the most commonly used ones are copper, iron, nickel, gold and silver. Some companies have recently been working with aluminum and alloys. Small items such as waveguides have constituted the main type of parts fabricated by electroforming. Thickness tolerances for waveguide walls are generally plus or minus .001" - .002". This can be held to closer tolerances, in the ten thousandths range if necessary. Due to the nature of the process parts can be made having almost identical dimensions, particularly inside dimensions. The metal deposits on the mandrel and duplicates its shape and surface finish almost exactly. If the mandrel has a highly polished surface the interior surface of the part produced on it will also.

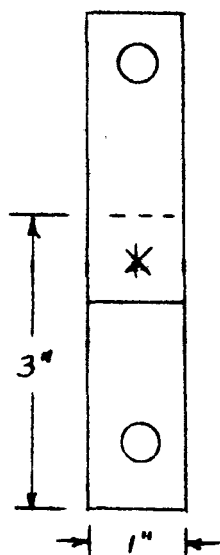
Two areas in which electroforming could be used in the Atlas and Centaur structures are the rings and bulkheads. Of the metals that could be deposited by the electroform process nickel appeared to hold the most promise because of its relatively high strength, excellent toughness at cryogenic temperatures and the possibility of being able to spotweld it to thin gauge extra full hard type 301 stainless steel presently used as tank walls.

#### PROCEDURE AND RESULTS:

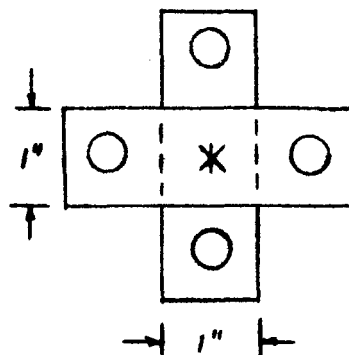
To determine the actual strength and toughness of electroformed nickel standard smooth and notched tensile specimens were cut and machined from nominal .062" thick material supplied by an outside vendor and tested at 78°F and -423°F by immersion in liquid N<sub>2</sub>. The results are tabulated in Table I. The  $F_{ty}$  (KSI),  $F_{tu}$  (KSI) and  $e$  averaged 86, 139, 7.5 at +78°F and 109, 184, 15.9 at -423°F. The toughness of the material, as evaluated by the notched tensile test, was excellent, having a notched-unnotched ratio of 1.21 at room temperature and 1.17 at -423°F.

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Weldability experiments were conducted on production resistance welding equipment at Astronautics. It was found that a spotweld nugget could be formed between .062" electroformed nickel and .020" - 301 stainless steel (Spec. O-71004) meeting the internal quality and penetration requirements of MIL-W-6858A. It was not necessary to use a .020" stainless steel doubler on the 301 side as had been the case when .060" Inconel-X was welded to .020" - 301 (Reference, MRG-134). To ascertain spotweld shear strength and toughness, several shear and cross-tension type specimens were made and tested at room temperature and -423°F. The specimen configurations are shown below:



Single Spot  
Shear Specimen



Single Spot  
Cross-Tension Specimen

A total of twelve cross-tension and shear spotweld specimens were tested at +78°F and -423°F, see Table II. The room temperature shear strengths of the single spotwelds averaged 1025 lbs., well above the minimum of 530 lbs. for .020" stainless steel required by MIL-W-6858A. Paragraph 4.15 of this specification also requires that, "materials previously not welded in production shall require establishment of non-hardening and weld ductility characteristics. This evaluation shall be conducted without special heating sequence applied purposely to temper the weld. Such welded material shall exhibit a tension strength not less than 25 percent of the minimum shear strength requirements."

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As seen from the data in Table II the tension strength of spotwelds in electroformed nickel welded to extra full hard type 301 stainless steel were 102% (at +78°F) and 63% (at -423°F) of the shear strength, well above the required minimum of 25%. Table II also compares the spotweld tension and shear strengths of Inconel-X welded to type 301 and type 301 welded to itself. The averages are compared below:

|                           |        | Cross<br>Tension<br><u>Lbs</u> | Shear<br><u>Lbs</u> | Tension -<br>Shear<br><u>Ratio</u> |
|---------------------------|--------|--------------------------------|---------------------|------------------------------------|
| .062" Electroformed Ni to |        |                                |                     |                                    |
| .020" - 301               | 78°F   | 1045                           | 1025                | 1.02                               |
|                           | -423°F | 1107                           | 1753                | 0.63                               |
| .060" Inconel-X to .020"  |        |                                |                     |                                    |
| - 301                     | 78°F   | 870                            | 1077                | 0.81                               |
|                           | -423°F | 402                            | 1663                | 0.24                               |
| .020" - 301 to .020" -    |        |                                |                     |                                    |
| 301                       | 78°F   | 486                            | 634                 | 0.77                               |
|                           | -320°F | 164                            | 856                 | 0.19                               |

#### CONCLUSIONS:

On the basis of the limited data it is concluded that electroformed nickel can be resistance welded to type 301 stainless steel with resultant spotwelds that meet the quality, shear and tension requirements of MIL-W-6858A. Of particular significance for integral bulk-head applications at LH<sub>2</sub> temperatures is the toughness and load carrying ability of the spotweld when loaded in tension. Spotweld tension strengths of .020" - 301 stainless steel welded to .062" electroformed nickel actually increased at -423°F as compared to spotweld tension strengths in .020" type 301 welded to Inconel-X and to .020" type 301 which decreased at cryogenic temperatures.

#### Reference:

- (1) MRG-134, Evaluation of Inconel -X to 301 Stainless Steel Resistance Spotwelds at 78°F and -423°F, by J. L. Christian 18 Feb. 1964

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TABLE I

MECHANICAL PROPERTIES OF ELECTROFORMED NICKEL  
AT ROOM TEMPERATURE AND -423°F

| <u>Test<br/>Temp.</u> | <u>Thickness<br/>Inches</u> | <u>F<sub>ty</sub><br/>KSI</u> | <u>F<sub>tu</sub><br/>KSI</u> | <u>*<br/>% in<br/>2"</u> | <u>Notched<br/>Tensile<br/>KSI<br/>(K<sub>t</sub>=6.3)</u> | <u>e %<br/>Across<br/>Notch</u> | <u>Notched/<br/>Unnotched<br/>Tensile<br/>Ratio</u> |
|-----------------------|-----------------------------|-------------------------------|-------------------------------|--------------------------|--|---------------------------------|---|
| RT                    | .066                        | 90.8                          | 147                           | 7.5                      |  |                                 |   |
|                       | .067                        | 81.0                          | 131                           | 7.5                      |  |                                 |   |
|                       | .062                        | —                             | —                             | —                        | 169  | 1.0                             | —   |
|                       | Avg.                        | 85.9                          | 139                           | 7.5                      | 169  | 1.0                             | 1.21  |
| -423°F                | .072                        | 104                           | 192                           | 7.5                      |  |                                 |   |
|                       | .062                        |                               | 165                           | 24.0                     | 169  | 1.0                             |   |
|                       | .062                        | 105                           | 200                           | 15.0                     |  |                                 |   |
|                       | .062                        | 119                           | 177                           | 17.0                     |  |                                 |   |
|                       | .067                        |                               |                               |                          | 215  | 1.5                             |   |
|                       | .062                        |                               |                               |                          | 221  | 2.0                             |   |
|                       | .062                        |                               |                               |                          | 217  | 2.0                             |   |
|                       | .060                        | —                             | —                             | —                        | 212  | 1.5                             | —   |
|                       | Avg.                        | 109                           | 184                           | 15.9                     | 216  | 1.75                            | 1.17  |

TABLE VI

Comparison of Spotweld Tension and Shear Tests of Electroformed Nickel, Inconel-X and Type 301 Stainless Steel Spotwelded to Type 301 Stainless Steel

| 0.062" Electroformed Nickel Spotwelded to 0.020" Type 301 Stainless Steel, Spec. 0-71004 |   |                                       |                     | 0.060" Inconel X Spotwelded to 0.020" Type 301 Stainless Steel Spec. 0-71004, with 0.020" Stainless Steel Tab over the 301 Sheet |   |                                       |                     | .020" Type 301 Stainless Steel, Spec. 0-71004 Welded to .020" Type 301 Stainless Steel |   |                                       |                     |
|--|---|---------------------------------------|---------------------|--|---|---------------------------------------|---------------------|--|---|---------------------------------------|---------------------|
| Test Temp. of  | Cross-Tension Strength of Single Spotweld Lbs | Shear Strength of Single Spotweld Lbs | Tension-Shear Ratio | Test Temp. of  | Cross-Tension Strength of Single Spotweld Lbs | Shear Strength of Single Spotweld Lbs | Tension-Shear Ratio | Test Temp. of  | Cross-Tension Strength of Single Spotweld Lbs | Shear Strength of Single Spotweld Lbs | Tension-Shear Ratio |
| +78°F  | 1000  | 990                                   |                     | +78°F  | 820   | 1115                                  |                     | +78°F  | 445   | 616                                   |                     |
|  | 1125  | 1065                                  |                     |  | 790   | 1090                                  |                     |  | 520   | 610                                   |                     |
|  | 1010  | 1020                                  |                     |  | 940   | 1090                                  |                     |  | 479   | 598                                   |                     |
| Ave. 1045  | Ave. 1025                                     |                                       | 1.02                | Ave.   | 870   | 1077                                  | 0.81                | Ave.   | 506   | 600                                   |                     |
|  |   |                                       |                     |  |   |                                       |                     |  | 486   | 745                                   | 0.77                |
| -423°F   | 1385  | 1675                                  |                     | -423°F   | 400   | 1600                                  |                     |  |   | 634                                   |                     |
|  | 1135  | 1785                                  |                     |  | 425   | 1685                                  |                     |  |   |                                       |                     |
|  | 800   | 1800                                  |                     |  | 375   | 1495                                  |                     | -320°F   | 170   | 814                                   |                     |
| Ave. 1107  | Ave. 1753                                     |                                       | 0.63                |  | 375   | 1670                                  |                     |  | 182   | 874                                   |                     |
|  |   |                                       |                     | Ave.   | 435   | 1865                                  | 0.24                |  | 150   | 800                                   |                     |
|  |   |                                       |                     |  | 402   | 1663                                  |                     |  | 152   | 880                                   |                     |
|  |   |                                       |                     |  |   |                                       |                     | Ave.   | 164   | 910                                   | 0.19                |
|  |   |                                       |                     |  |   |                                       |                     |  | 164   | 856                                   |                     |

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